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13. ABSTRACT *(Maximum 200 words)*

 The primary objective of this research program is to develop and apply mathematical tools for the purposes of process discovery. Our focus is on empirically based methods applied to massive data sets in a high-dimensional setting. The emphasis of the program is on applications of direct interest to the Air Force. In particular, we have been investigating problems of interest to Air Force Research Laboratory, Materials & Manufacturing Directorate, Materials Process Design Branch at Wright Patterson Air Force base. Lately, we have intended the work to a problem of interest to the United States Forest Service.

Recent work includes the application of subspace noise reduction methods and their connection to blind source separation. We have established a theoretical connection between the maximum noise fraction method and independent component analysis and demonstrated the relationship with examples. This methodology has proven useful as an integral component of the Whitney Reduction Network, developed by the grantees.

Additionally, a new approach for designing support vector machines has been developed for the classification problem using a kernel based Fisher discriminant method. In addition we have developed other algorithms in terms of kernel functions using a kernel Grim-Schmidt algorithm These techniques have been applied to the materials science bonding problem.

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Final Report
A Reductionist Approach to Process Discovery
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Submitted Papers, Dissertations and Publications

Dissertation:

Shawn Martin, Techniques in Support Vector Classification, Department of Mathematics, Colorado State University, Fort Collins, CO 80524

Master's Paper:

Anthony Todd, Data Visualization via Structured Voronoi Cell Refinement.

Submitted:

- M. Anderle and M. Kirby, Radial Basis Function Networks based on Autocorrelation Feedback Resource Allocation, submitted for publication 2001 to Neural Computation (under review)

Accepted:

- D. Hundley and M. Kirby, Automated Estimation of Topological Dimension, to appear in Proceedings of the SDM03, San Francisco, May 2003 (a SIAM refereed conference in Scientific Data Mining).

Published:

1. Michael Kirby and Charles Anderson, Geometric Analysis for the Characterization of Nonstationary Time Series, in Perspectives and Problems in Nonlinear Science: A Celebratory Volume in Honor of Larry Sirovich, Editors: Ehud Kaplan, Jerrold E. Marsden, Katepalli R. Sreenivasan, March 2003.

2. Douglas R. Hundley, Michael J. Kirby, and Markus Anderle, Blind source separation using the maximum signal fraction approach, Douglas R. Hundley, Michael J. Kirby, and Markus Anderle, Signal Processing Volume 82, Issue 10, October 2002, Pages 1505-1508

3. M. Anderle, D. Hundley and M. Kirby, The Bilipschitz criterion for mapping design in data analysis, Intelligent Data Analysis, Volume 6, Number 1, 2002, pages 85--104.

4. M. Anderle and M. Kirby, An Application of the Maximum Noise Fraction Method to Filtering Noisy Time-Series, in Mathematics in Signal Processing V, Editors: J. G. McWhirter and I. K. Proudler, Oxford University Press, June 2002.

5. M. Anderle and M. Kirby, Correlation Feedback Resource Allocation RBF, Proceedings of the International Joint conference on neural Networks, vol 3., pages 1949-1953, 2001.

6. D.S. Broomhead and M. Kirby, The Whitney Reduction Network: a method for computing autoassociative graphs, Neural Computation 13:2595-2616, 2001.

7. M. Anderle, M. Kirby, and A. Todd. Identifying Structure in High-Dimensional Data Sets using Connectivity Matrices. SIAM Workshop on Mining Scientific Datasets. Chicago, pages 29-36. April 7, 2001.

8. D. Hundley, M. Kirby and Markus Anderle, A Solution Procedure for Blind Signal Separation using the Maximum Noise Fraction Approach: Algorithms and Examples, Proceedings of the Conference on Independent Component Analysis, San Diego, CA, pages 337--342., December, 2001

9. Anthony Todd and M. Kirby. Data Visualization via Structured Voronoi Cell Refinement. SIAM Workshop on Mining Scientific Datasets. Chicago, pages 45-52. April 7, 2001.

10. Michael Kirby, *Geometric Data Analysis*, Wiley & Sons 2001

11. Shawn Martin, Michael Kirby and Rick Miranda, Kernel/Feature Selection for Support Vector Machines Applied to Materials Design, to appear in Engineering Applications of Artificial Intelligence 2001.

12. M. Anderle and M. Kirby, Filtering Noisy Time Series: Keeping the Baby and Most of the Bathwater, Conference Digest, Fifth IMA International Conference on Mathematics in Signal Processing, Univeristy of Warwick, 2000

13. D.S. Broomhead and Michael Kirby, A New Approach for Dimensionality Reduction: Theory and Algorithms, SIAM Journal on Applied Mathematics, Volume 60, Number 6 pp. 2114-2142, 2000

14. Time series prediction by estimating Markov probabilities through topology preserving maps, (with G. Dangelmayr and S. Gadaleta and D. Hundley), Proc. SPIE Vol. 3812, In: Applications and Science of Neural Networks, Fuzzy Systems, and Evolutionary Computation II, 86--93, Editors B. Bosacchi and D. B. Fogel and J.C. Bezdek, 1999

15. A New Optimal Basis for Image Representation, (with D. Dreisigmeyer), Proc. SPIE Vol. 3814, Mathematics of Data/Image Coding, Compression and Encryption II, Editor M. Schmalz, 1999

16. Adaptive Clustering Based on Local Neighborhood Interactions, (with Markus Anderle), Proc. SPIE Vol. 3807, Advanced Signal Processing Algorithms, Architectures, and Implementations IX, Editor Franklin T. Luk, 1999

Travel and Conferences, Seminars

- D. Hundley, M. Kirby and Markus Anderle, A Solution Procedure for Blind Signal Separation using the Maximum Noise Fraction Approach: Algorithms and Examples, ICA 2001, **San Diego**, December 2001

- M. Anderle, M. Kirby, and A. Todd. Identifying Structure in High-Dimensional Data Sets using Connectivity Matrices. SIAM Workshop on Mining Scientific Datasets. **Chicago**, pages 29-36. April 7, 2001.

- Anthony Todd and M. Kirby. Data Visualization via Structured Voronoi Cell Refinement. SIAM Workshop on Mining Scientific Datasets. **Chicago**, pages 45-52. April 7, 2001.

- Michael Kirby, Image Fusion, Electronic Prototyping Review, Boeing, **Seattle**, July 2001.

- M. Anderle and M. Kirby, Correlation Feedback Resource Allocation RBF, Proceedings of the International Joint Conference on Neural Networks, vol 3., pages 1949-1953, **Washington D.C.**, July 2001.

- Dave Broomhead, visited Colorado State University, **Fort Collins**, October 2000

- Anthony Todd visited the materials science group at WPAFB, **Dayton**, in October 2000.

- Michael Kirby, Filtering Noisy Time Series: Keeping the Baby and Most of the Bathwater, Fifth IMA International Conference on Mathematics in Signal Processing, University of Warwick, U.K., Dec 18, 2000

- Shawn Martin, Kernel/Feature Selection for Support Vector Machines Applied to Materials Design, IFAC Symposium on Artificial Intelligence in Real Time Control 2000, Budapest, October 2000

- Michael Kirby, Dimensionality Reduction via Well Conditioned Mappings, Fourth International Congress on Industrial and Applied Mathematics, Edinburgh, Scotland, July 1999.

- Michael Kirby and Shawn Martin, AFRL/MLMR Researchers Meeting, The Ohio State University, Columbus, OH, 26 November 1999.

- Michael Kirby, Department of Mathematics Seminar, Multiresolution Analysis, April 1999

- Michael Kirby, Department of Mathematics Seminar, Radial Basis Functions, September 1999

- Shawn Martin, Seminar in Applied Mathematics, Veronese mappings, October 1999.

- Michael Kirby, Whitney Reduction Networks, AFIT Colloquium, Wright-Patterson AFB, OH, 29 September 1998.

- Mark Oxley, Artificial Intelligence in Real-Time Control, Grand Canyon National Park, AZ, 5-8 October 1998.

- Mark Oxley, The Functional and Harmonic Analysis of Wavelets, AMS Special Session at the AMS Joint Mathematics Meetings, San Antonio, TX, 13 January 1999.

- Mark Oxley, AFRL/MLMR Researchers Meeting, The Ohio State University, Columbus, OH, 2 April 1999.

- Martha A. Carter and Mark E. Oxley, Generalized Measures of Artificial

- Neural Network Capability, Applications and Science of Computational Intelligence II, SPIE conference, April 1999.

- Mark E. Oxley and Martha A. Carter, Evaluating the VC dimension using the Poincare Polynomial}, Applications and Science of Computational Intelligence II, Proceedings of SPIE conference, April 1999.

- Mark Oxley, AFOSR review, Minnowbrook Conference Center, NY, 16-18 April 1999.

- Mark Oxley, Evaluating the VC dimension using the Poincare Polynomial}, Mathematics Seminar, Colorado State University, Fort Collins, CO, 18 May 1999.

- Mark Oxley, Symmetric Veronese Classifers, AFOSR Electronic Prototyping Review, AFIT, Wright-Patterson AFB, OH, 8 July 1999.

- Mark Oxley, Whitney Reduction Network for Process Discovery, Second International Conference on Intelligence Processing and Manufacturing of Materials (IPMM'99), 15 July 1999.

Transitions

Additional Grants Transitioned From This Award:

- PI Michael Kirby, Title: Wavelet Analysis for Detecting and Characterizing Landscape Scale Patterns of Forest Disturbance, Funding Source: United States Forest Service, 7/30/01-6/1/02, $11,000.

- PI Michael Kirby, Image Mining of Sensed Data, Funding Source, Technical Management Concepts, Inc., Funding 10/15/00--9/30/01, $16,977.

- CO-PI Michael Kirby, Geometric Pattern Analysis & Mental Task Design for a Brain-Computer Interface, Funding approximately $800,000 over 4 years. (Charles Anderson, CSU, PI).

- PI Michael Kirby, Development of a MATLAB Novelty Detection Algorithm, summer 2000, $50,000, Honeywell Corporation.

Student Transitions:

- Shawn Martin Ph.D. 2001 was supported by this grant and was awarded a postdoctoral fellowship at Sandia National Labs.

- Anthony Todd, Master's 2001 was supported by the related spin-off grant by Technical Management Concepts to address Air Force materials science problems sponsored by Steve LeClair (Wright Patterson). He has now graduated and is employed in the data fusion group at Lockheed Martin.

Consultative and advisory functions to other laboratories and agencies, especially Air Force and other DoD laboratories.

The personnel supported by this grant have been working with Dr. Steve LeClair, AFRL/MLMR, (937) 255-8787 and his Branch to determine bonding properties of materials. Dr. Pierre Villars, Material Phases Data System (MPDS), Switzerland, has data on binary and ternary compounds (Villars is funded by AFRL). We have been working with this data to discover features that determine when a compound will form. In addition, Anthony Todd and Michael Kirby have worked with Dr. LeClair for image mining of sensed data.

The data reduction techniques initiated here have been extended to the application of failure prediction and asset analysis. Using this technology, we developed the "Asset Analyzer" toolbox that for Honeywell Corporation.

Awards During Period of Grant

1. IBM Faculty Award (Michael Kirby)
2. Colorado State University College of Natural Sciences Graduate Education Award (Michael Kirby)